Embodied decision making with animations

Lanini-Maggi, Sara ; Fabrikant, Sara I

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Embodied decision making with animations

S. Maggi and S. I. Fabrikant

University of Zurich, Department of Geography, Winterthurerstr. 190, CH –8057 Zurich, Switzerland.
Email: {sara.maggi, sara.fabrikant}@geo.uzh.ch

1. Introduction

Map animations have become popular devices to depict complex spatio-temporal phenomena. Intuitively, animations seem to be an ideal choice to depict moving objects over time (e.g., aircraft movements over an airport at a particular day), because real-world object movements are congruently depicted with graphical objects moving in a display (Tversky 2002). Visuo-spatial decision-making might not only be influenced by external stimuli (e.g., the perceptual salience and thematic relevance of visual cues), but also by a viewer's internal emotional state (e.g., mood or motivation) (Koelstra 2012). To gain more insights on users' perceptual, cognitive and emotional processes, we propose a long-term empirical research framework to empirically assess dynamic visuo-spatial displays, based on triangulation that couples eye movement data with electrodermal activity (EDA), electroencephalography (EEG), and traditional questionnaires (Holmqvist et al. 2011; Maggi and Fabrikant 2014).

We present a subset of preliminary results of a human-subject experiment in the context of air traffic control to monitor aircraft movements. We aim to investigate how *display-* (i.e., animation types), *data-* (i.e., characteristics of the depicted objects), and *user-related factors* (i.e., individual/group differences) might influence visuo-spatial decision-making with animations.

2. Methods

Standard air traffic control (ATC) displays typically show aircraft movements with semi-static animations in which aircraft positions are refreshed every 4s. Following a mixed factorial design, we set out to investigate how the independent variables *display design* (i.e., semi-static vs. continuous aircraft movements), aircraft *movement dynamics and context* (i.e., varying speeds and number of displayed aircrafts), and *user characteristics* (i.e., ATC expertise, spatial ability, and psycho-physiological state) might influence the accuracy and speed of aircraft movement detection (i.e., dependent variables). Figure 1 shows a static version of a stimulus, inspired by French air traffic control (ATC) radar screens, representing four aircrafts moving at different speeds in the same direction.

In a between subject design, we asked eighteen air traffic controllers at the Ecole Nationale de l'Aviation Civile (ENAC) in Toulouse (e.g., ATC experts), and nineteen psychology students at Temple University in Philadelphia (e.g., ATC novices) to watch sixteen semi-static and sixteen continuous animations (N=32), and to click on the accelerating aircraft as soon as they detected it. Animations were presented digitally on a color monitor at 1920x1200 spatial (pixel) resolution. Participants had the possibility to stop the animation, once they identified the accelerating aircraft. On average, the animated portion of the experiment took about 16 minutes. Before and after being shown the animated displays, participants filled in a Short Stress State Questionnaire (SSSQ) that captures three individual factors of subjective stress, i.e., task engagement, distress, and worry (Helton et al. 2004). We recorded participants' eye movements, electrodermal activity, and EEG during the entire experiment.

Figure 1. Sample stimulus with four aircrafts moving from left to right.

3. Results and Discussion

We present a subset of our results, focusing on the dependent variables: response accuracy (Maggi and Fabrikant 2014) and EDA, across the independent variables animation design (i.e., semi-static vs. continuous animations), and users' ATC expertise levels (i.e., experts vs. novices). Figure 2 graphs response accuracy across animation type and expertise.

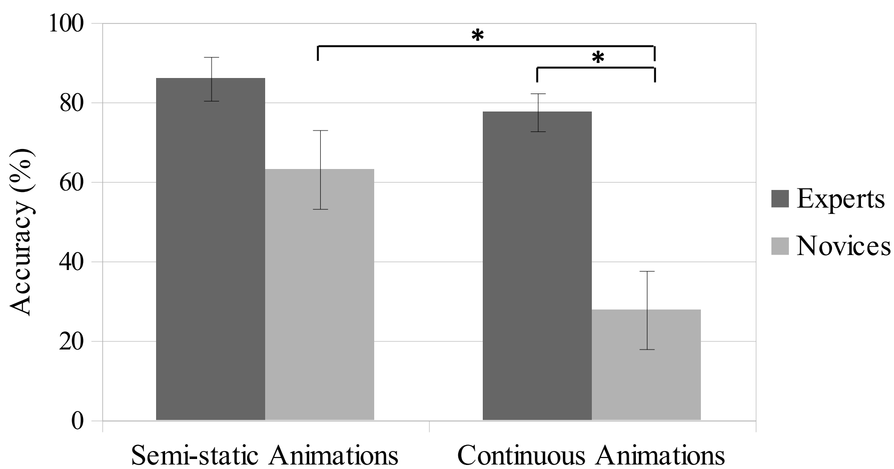


Figure 2. Mean response accuracy for ATC experts and novices across animation design conditions (error bars show standard error).

On average, response accuracy of novices is significantly higher ($F(1,17)=6.38$, $p<.022$) with semi-static displays (63%), compared to continuous displays (28%). Irrespective of display design, experts are more accurate than novices (i.e., close to 80%), but this difference is only significant for the continuous animation condition ($F(1,17)=22.19$, $p<.000$). We further analyzed participants' arousal response intensity that might have affected response accuracy. As shown in Figure 3 below, we compare the standardized, average area (i.e., integral) bounded by the SCR curve of the phasic EDA by trials, across expertise level and animation design conditions (Boucsein 1992; Lykken and Venables 1971).

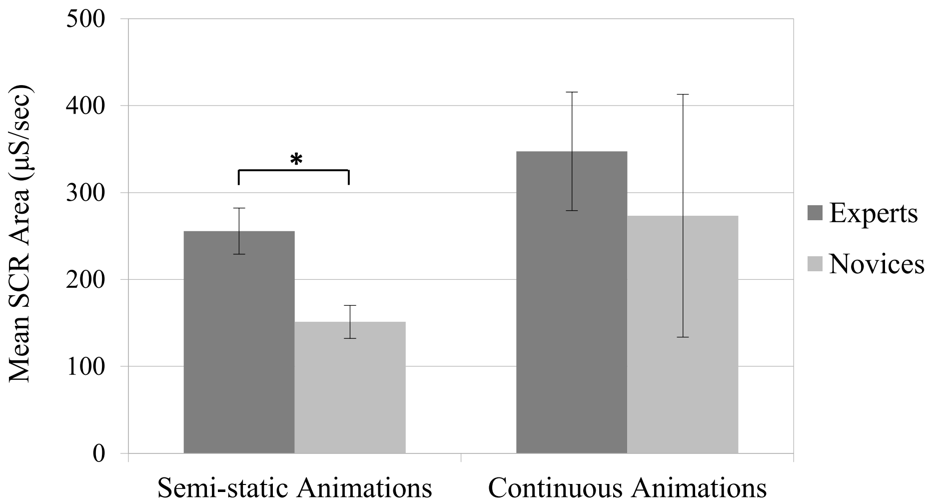
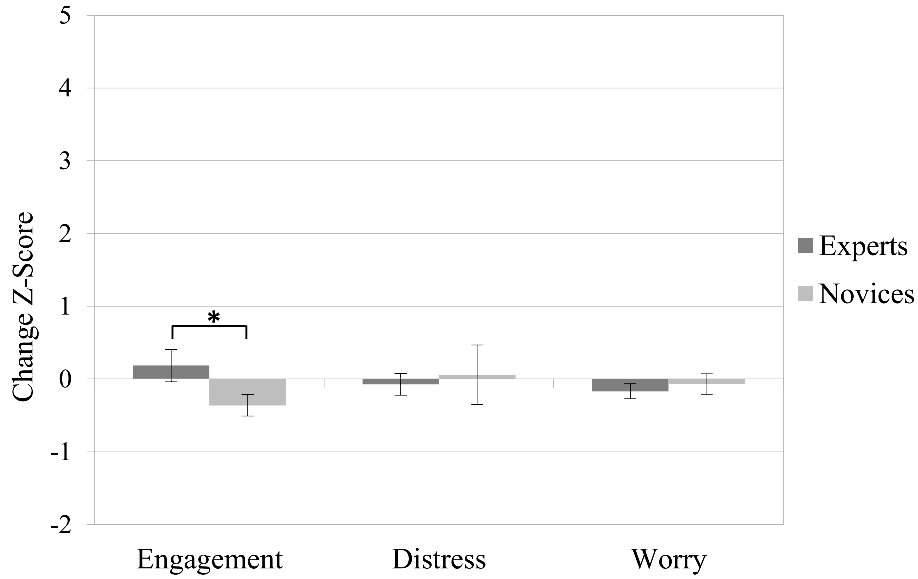


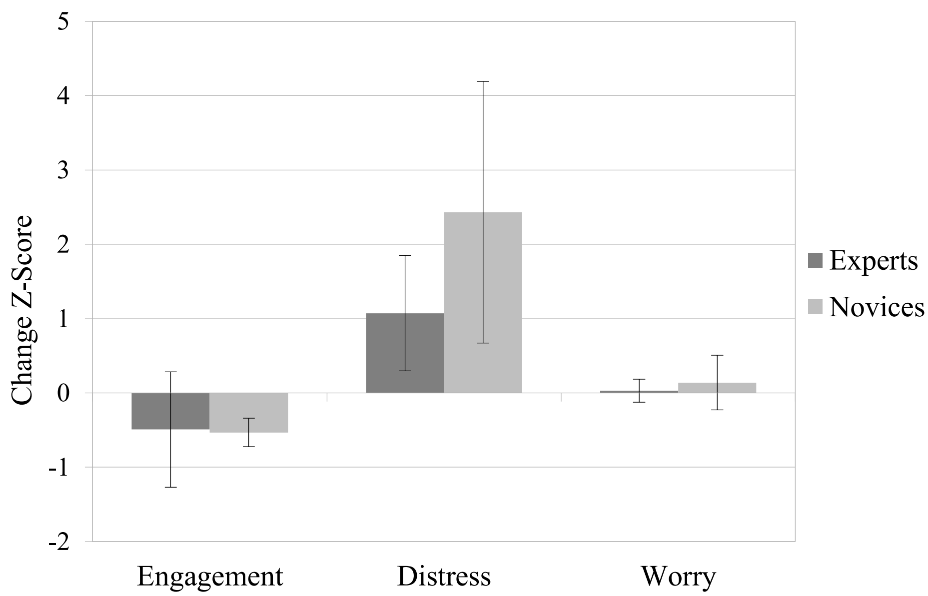
Figure 3. Mean area bounded by the SCR curve for ATC experts and novices across animation design conditions.

We only analyzed a subset of 20 participants to date (13 experts and 7 novices), due to noise in the recorded SCL data. We find that on average experts show higher arousal levels than novices (Figure 3). However, this arousal response density difference is only significant for the semi-static animations, due to large variances in the continuous animation condition. We additionally investigated participants' stress factor states that might further explain SCR differences, i.e., engagement, distress and worry, captured with the SSSQ (Helton et al. 2004). Figure 4 details change z-scores across animation type and expertise level. Experts show more engagement and less distress and worry with the familiar semi-static animations, compared to novices (Figure 4a). The difference is only barely significant for the factor engagement ($t(16)=3.00$, $p<.050$), probably again because of the large variance in the novice population. This picture is almost mirrored for the continuous animation condition (Figure 4b). Now experts and novices show similar low engagement patterns, but novices exhibit more distress and worry than experts. None of the SSSQ score differences are significant in the continuous animation condition (Figure 4b), however. This might again be due to the large variance in the novice group. Significant differences both found in arousal levels and SSSQ scores between experts and novices for the semi-static animation condition might have a relevant relationship that needs further investigation.

While experts perform the experimental task more accurately than novices overall, irrespective of the animation design, they appear to have been less engaged, and more distressed with the unfamiliar continuous animation type. Higher distress levels coupled with worry might explain novices' even lower response accuracy with the continuous animations, compared to those of the experts. Conversely, being less distressed and less worried with the semi-static condition, had a positive effect on response accuracy for novices, compared to their low performance in the continuous animation condition. In fact, anecdotal evidence from open-ended questionnaires suggests that novice participants found it much more difficult to solve tasks with the continuous animations than with the semi-static ones. Familiarity with a display (i.e., training) seems to have a greater effect on decision-making accuracy than novelty of display design.



(a) Semi-static animations.



(b) Continuous animations.

Figure 4. SSSQ change z-scores across expertise across animation types.

4. Summary and Outlook

We presented preliminary results of a first study within a novel empirical, embodied research framework to assess animated visual displays based on psycho-physiological data triangulation. Our results confirm previous animation studies suggesting that prior knowledge and display design influence visuo-spatial decision-making with animated graphical displays (Kriz and Hegarty 2007). By specifically quantifying participants' arousal and stress factor states, analyzed across expertise levels, we are able to more deeply investigate how cognitive, perceptual, and psycho-physiological processes might affect the effectiveness of animation design in the context of air traffic control. We intend to further include collected EEG data streams and eye movement recordings in our analysis to better disentangle emotional, cognitive and perceptual factors from display design and task contexts. We will also further investigate event-related electrodermal activity, as there is a known positive relationship between physiological arousal and task performance (Yerkes and Dodson 1908).

We are currently designing follow-up experiments to further investigate how the inclusion of contextual information (e.g., a wind map), and the increase of perceptual salience (e.g., through visual variables) might affect decision-making with animated displays.

With the empirical results of this user-centered empirical research agenda we hope to develop general design guidelines for perceptually salient, affectively engaging, and cognitively inspired animations that support effective and efficient visuo-spatial exploration and decision-making of spatio-temporal phenomena and processes.

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